The effect of smartphone application interventions on physical activity level among university/college students

Physical Therapy Reviews

The Effect of Smartphone Application Interventions on Physical Activity Level Among University/College Students: A Systematic Review Protocol

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Abstract:	Introduction: Strong evidence has shown the benefits of engagement in recommended amount of physical activity. However, it is estimated that nearly half of university students do not participate in sufficient amount of physical activity. While entering university life is a transitional stage important for adopting a particular lifestyle, it is crucial to develop and implement novel strategies to promote physical activity among this population. A smartphone application is a potential media for delivering physical activity intervention. However, recent reviews in this area have demonstrated high levels of heterogeneity, potentially due to population diversity. To date there has been no attempt to synthesize the literature assessing the effectiveness of this particular intervention in university students. Aim: The primary aim of this review is to investigate the effectiveness of smartphone application intervention on physical activity level among university students. The secondary aim is examining the behavior change technique elements of smartphone applications used in available studies. Methods: Sixteen electronic databases will be searched for randomized controlled trials and quasi-experimental studies reporting the effect of smartphone application intervention on physical activity outcomes among university students. Two reviewers will independently screen the potential studies and extract data from included studies. Active elements of smartphone applications used in included studies will be coded using the Behavior Change Technique taxonomy v1. Risk of bias and quality of evidence of individual studies will be assessed. The overall evidence will be presented in a narrative synthesis and quantitative synthesis.
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The Effect of Smartphone Application Intervention on Physical Activity Level Among University/College Students: A Systematic Review Protocol

Introduction: Strong evidence has shown the benefits of engagement in recommended amount of physical activity. However, it is estimated that nearly half of university students do not participate in sufficient amount of physical activity. While entering university life is a transitional stage important for adopting a particular lifestyle, it is crucial to develop and implement novel strategies to promote physical activity among this population. A smartphone application is a potential media for delivering physical activity intervention. However, recent reviews in this area have demonstrated high levels of heterogeneity, potentially due to population diversity. To date there has been no attempt to synthesize the literature assessing the effectiveness of this particular intervention in university students.

Aim: The primary aim of this review is to investigate the effectiveness of smartphone application intervention on physical activity level among university students. The secondary aim is examining the behavior change technique elements of smartphone applications used in available studies.

Methods: Sixteen electronic databases will be searched for randomized controlled trials and quasi-experimental studies reporting the effect of smartphone application intervention on physical activity outcomes among university students. Two reviewers will independently screen the potential studies and extract data from included studies. Active elements of smartphone applications used in included studies will be coded using the Behavior Change Technique taxonomy v1. Risk of bias and quality of evidence of individual studies will be assessed. The overall evidence will be presented in a narrative synthesis and quantitative synthesis.

Keywords: exercise; m-health; physical activity; smartphone applications; university students

Introduction

Several studies have shown the health benefits of sufficient levels of physical activity (PA) for people of all ages [1,2]. They have demonstrated the role of PA in both prevention and treatment of several non-communicable diseases, such as coronary heart disease, hypertension, stroke, certain cancers, as well as mental health disorders such as depression and anxiety. Since maintaining and restoring functional ability throughout the lifespan are the aims of physical therapy, physical activity is an important aspect of physical therapy [3]. The World Health Organization [4] recommends that adults should engage in at least 150 minutes of moderate-intensity PA or 75 minutes of vigorous-intensity PA throughout the week which could be accumulated from at least 10 minutes bouts of PA. This amount is equivalent to 7000 steps/day [5] or 600 MET.minutes/week [6].

Performing an insufficient amount of PA is referred to as physical inactivity [7]. Nowadays, physical inactivity becomes the fourth leading risk factor of mortality [8]. Almost one in three adults are not meeting the minimum recommendation for PA [9]. The problems of physical inactivity are striking among university students. Nearly 50% of university students are physically inactive [10]. Entering a university is considered as a transitional life stage when students begin to make their own decision for adopting a lifestyle in later life [11]. Thus, it is crucial to develop and implement novel strategies to promote PA among university students.

A smartphone could be leveraged as a communication channel for delivering PA intervention to university students. The number of smartphone users is rapidly growing, which was projected to reach 48% of adults by 2021 [12]. According to Statista [13], young adults have the highest engagement to smartphone applications among all age

group. Since over than 75% of university students are young adults aged 17-27 years [14], a smartphone application could get high engagement from this population.

Smartphone applications promoting physical activity are software developed for consumer mobile electronic devices, such as smartphones and tablets, which aim to motivate PA behavior. These applications, including fitness-specific applications, gaming applications, or social media applications, could provide individually tailored PA intervention containing behavior change techniques (BCTs) [15]. The applications could promote PA behavior since they could contain BCTs which were associated with PA intervention effectiveness, such as a combination of self-monitoring and goal setting, feedback on performance, or other behavior change techniques from control-theory [16, 17, 18, 19, 20].

Previous literature reviews provide evidence of promising results of smartphone applications for promoting PA behavior [21, 22, 23, 24, 25]. Evidence from non-randomized controlled trials found that smartphone apps could either increase PA, decrease PA, or prevent PA decline [21]. Romeo et al. [25] conducted a subgroup analysis on healthy adult across all ages that resulted in a small, inconclusive and high heterogeneous result (mean difference= +649,54 steps per day, 95% CI -822.66 to 21221.74, I^2 80%). Heterogeneous and inconclusive results from previous systematic reviews could be attributable, in part, to various population.

To date, there has been no attempt to synthesize the literature assessing the effectiveness of this particular intervention in university students. Craig et al. [26] suggested that identifying the BCT component of complex intervention, including physical activity intervention, could help in understanding the effectiveness of the intervention. However, there has been no attempt to describe BCTs utilized in the available studies of PA intervention incorporating smartphone applications.

Aims of review

This systematic review will investigate the effectiveness of PA intervention utilizing smartphone applications among university students. In addition, the secondary aim of this review is examining the behavior change techniques (BCTs) used in available studies.

Methods

This systematic review protocol has been reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines [27] and has been registered in the International Prospective Registers of Systematic Reviews (PROSPERO) (registration number CRD42019137417).

Eligibility criteria

Participants

Studies will be eligible for inclusion if they were conducted in healthy university students, or young adults aged 18-35 years old with tertiary education level. Studies with participants characterized by intellectual or marked cognitive impairments or with a severe mobility disorder and chronic diseases, or trained athletes will be excluded. Studies recruiting university staff or other general populations will be considered to be included if their average age was in young adult age range (considered as 18-35 years) and more than 70% of their participants were university students, or they presented results of sub-group analysis allowing data from university students to be extracted. Primary reviewer will contact the author(s) of potential studies if they did not provide a clear proportion of university students or if they could provide the subgroup analysis on university students. Only studies measuring PA at an individual level will be included.

Intervention

Studies incorporating smartphone applications as an intervention targeting either physical activity as a single target behavior or physical activity as a part of multiple target behavior will be included. Short text message application or web-based intervention will be excluded since smartphone apps could contain more comprehensive and interactive components [20].

Comparator

For inclusion in the review, studies had to compare physical activity intervention incorporating smartphone application to other kinds of physical activity intervention, including usual care such as physical activity promotion brochure, or to studies incorporating smartphone app which do not have a physical activity component, or to conditions without any intervention such as waiting-list control.

Outcome measures

Primary outcomes: Studies that either objectively or subjectively assess change between baseline and follow-up for PA level will be included. PA level could be expressed as an estimate of total energy expenditure (kcal/kg/week or kcal/week or MET.minutes/week), minutes completed or energy expensed at a moderate-vigorous physical activity (MVPA), the number of steps, or walking distance.

Secondary outcomes: As suggested by the CONSORT-EHEALTH checklist [28], the secondary outcomes of this review will include data relevant to participants' perception of interventions, engagement and usage rates of the app if possible.

Information sources and search strategy

A systematic search will be conducted on 16 electronic databases (Table 1); by two independent reviewers. In brief, the search strategy will combine indexed terms and free terms for the population ([{university OR college OR first-year OR university-age OR college-age OR higher education OR post-secondary OR tertiary education OR medical OR dentist OR nursing OR pharmacist} AND {age OR year OR student*] OR young adult), intervention ([physical activity OR PA education OR health education OR PA Promotion OR physical education OR health promotion OR exercise OR weight loss } AND {smartphone OR assess OR smart-phone OR mobile phone OR mobile device OR cell phone OR mobile OR m-health OR android OR iPhone OR app OR application OR digital).

We will also search for current and ongoing trials such as the World Health Organization – International Clinical Trials Registry Platform (WHO ITCRP) and ClinicalTrials.gov. Then, we will contact the authors for any unpublished results.

We will amend the search strategy used for MEDLINE (OVID) where necessary to search the other databases listed (Appendix 1). We will apply no language restriction to the searches. However, articles which were published in non-English language should have abstracts or titles in English. We will include such studies with English abstracts into the analysis if they can be easily translated into English using Google Translate. Studies with English headings or abstracts, but that cannot be translated into English, will remain as appendices.

Reference lists and links from PubMed of all primary studies and review articles will be checked for additional references. We will contact authors of identified primary studies for other published and unpublished studies which meet the review inclusion criteria as well as ongoing trials and relevant publications in press.

Data management

Having conducted the search strategy described above, the primary authors (RAW) will import the results from all literature searches into Endnote software and will remove duplicates using the software and manually remove any other duplicates.

Selection process

From scoping searches, several thousand citations are expected to be identified with the initial search strategy. The primary author (RAW) and second author (BN) will independently screen these titles and abstracts manually to exclude studies which do not meet the inclusion criteria. They will then screen the full-text of those studies to identify a final set of eligible studies. The second author (BN) will screen at least 10% of the potential studies. RAW and BN will also identify and record reasons for exclusion of the excluded studies. They will resolve any disagreements through discussion with involvement from a third author (GB) if required. The primary author (RAW) will record the selection process to complete a PRISMA flow diagram and "Characteristics of excluded studies" table.

Data extraction

Two authors (RAW and BN) will independently extract the following study characteristics (Table 2) from included studies according to the Consolidated Standards of Reporting Trials-EHEALTH (CONSORT-EHEALTH) checklist [28] into Excel using a data extraction form.

Data items

Two authors (RAW and BN) will independently code and extract items, except behavior change techniques (BCTs), using the following categories (Table 2).

Two authors (RAW and GB) will identify and code BCTs for all interventions using the BCT Taxonomy v1 [29]. This taxonomy was developed to help researchers in precisely characterizing and reporting the active contents of a behavior change intervention [29]. Containing 93 BCTs clustered into 16 groups, this taxonomy could be used to specify interventions [29]. The included studies which did not report outcome data in a useable way will be noted in the "Characteristics of included studies" table.

Risk of bias in individual studies

Two authors (RAW and GB) will assess the risk of bias for all eligible studies using the Cochrane Collaboration's tool for assessing the risk of bias in primary RCTs [30] and the Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I) tools for assessing the risk of bias in primary Quasi-Experimental studies [31]. The author will present a "Risk of bias" table for each study.

We will assess the primary RCT studies based on the quality of the random sequence generation, allocation concealment, blinding of outcome assessment, completeness of data and handling of incomplete data, the presence of reporting bias and other potential sources of bias including the validity of outcome measures, intention-to-treat analysis approach and comparability of groups at baseline [30,32]. We will not assess the primary RCT studies on whether participants and personnel were blinded to their group allocation since this would not be appropriate for a physical activity intervention study. We will rate each domain in the Cochrane Risk of Bias tool as "high" or "low" risk of bias if sufficient information is available. If there is a lack of information, we will rate the domain as "unclear."

We will assess quasi-experimental studies using ROBINS-I tool based on seven domains: bias due to confounding, bias in selection of participants into the study, misclassification bias, performance bias, attrition bias, detection bias, and reporting bias

[31]. We will rate each domain in the ROBINS-I tool as "Low," "Moderate," "Serious," or "Critical" risk of bias if sufficient information is available. If there is a lack of information on whether bias might be present in a domain, we will rate it as "No information."

Measures of treatment effect

For each study with dichotomous outcomes such as outcome categorized by the achievement of the recommended level of PA, we will calculate the effect size using an odds ratio (OR) and confidence interval (CI). For each study with continuous outcomes such as average energy expenditure, we will calculate the effect size using the mean difference (MD) if same measurement scale was used across the studies, and the standardized mean difference (SMD) if different measurement scale was used across the studies. We will interpret the treatment effect using a threshold of 675 MET.minutes/week or 3278 steps/day as minimally important difference for physical activity outcome [33, 34, 35].

Dealing with missing data

Primary author (RAW) will contact the original investigator of potentially included studies to request missing or unclear data. Missing data will be captured in the data extraction form and reported in the "Risk of bias" table. We will utilize the outcome from the longest period of follow up if an included study reported an outcome measure at more than one-time point.

Assessment of heterogeneity

We will assess the heterogeneity by examining the forest plot and calculating I^2 with upper limits of 25, 50, and 75 for low, moderate, and high heterogeneity, respectively

220 [36].

221 ***Assessment of reporting bias***

222 We will present a funnel plot to assess reporting bias if there are sufficient eligible studies
223 (10 or more).

224 ***Data synthesis***

225 First, the primary author (RAW) will present a narrative summary of the study results in
226 PA outcome structured around the type of the comparator, the type of the outcomes, and
227 the type of BCTs used. Then, we will conduct meta-analyses to generate an average mean
228 change in PA from the pooling of studies. We will utilize a random-effect model to
229 anticipate study heterogeneity because of the high variance of intervention designs. If
230 appropriate, the outcome meta-analyzed in this review will be the mean change in PA
231 level either reported as time spent in total PA or MVPA, total energy expenditure, step
232 count, or walking distance. The mean difference (MD) will be calculated when the same
233 measurement scale was used across the eligible studies. On the other hand, we will
234 calculate the standardized mean difference (SMD) when different measurement scale was
235 used across the eligible studies. The SMD will be interpreted using thresholds of 0.2, 0.5,
236 and 0.8 as a small effect size, medium effect size, and large effect size, respectively, as
237 suggested by Cohen [37].

238 ***Subgroup and sensitivity analysis***

239 We will perform subgroup analyses where appropriate and possible, to compare studies
240 that target single versus multiple behavior, RCTs versus quasi-experimental studies,
241 studies in healthy weight versus overweight [38], studies comparing smartphone apps
242 intervention with other kinds of intervention versus studies comparing smartphone apps

intervention with no intervention, studies with duration of 6 months or below versus longer than 6 months, and studies in male versus female [39].

We will perform a sensitivity analysis for studies that included university staffs, postgraduate students, Ph.D. students or young adults with low education level versus studies that only include undergraduate students because the age of participants and education level could influence the effectiveness of m-health intervention [40, 41]. We will also exclude studies delivering smartphone intervention with co-intervention in sensitivity analyses to isolate the effectiveness of smartphone intervention as a single intervention. Studies delivering intervention specifically for sports students will also be excluded in sensitivity analyses since sports students could have different motivation in sport participation than students in other faculties [42]. We will also conduct sensitivity analysis to assess the robustness of meta-analytic for study with a low risk of bias by conducting a meta-analysis with all eligible studies and another analysis which excludes studies with a high risk of bias.

Confidence in cumulative evidence

We will assess the quality of evidence for primary outcomes using the Grading of Recommendation, Assessment, Development and Evaluation (GRADE) approach [36].

Discussion

University students represent an important population to target for PA intervention because this age group typically do not meet physical activity guidelines [10]. Furthermore, the transition to university represents a critical period for adopting a particular lifestyle [11]. As far as we are aware, there has been no attempt to synthesize the literature exclusively assessing the effect of smartphone applications on physical activity level among university students. This review will be the first to evaluate the

effectiveness of physical activity intervention incorporating smartphone application in populations of university students. If there are sufficient homogenous data to conduct meta-analyses, this review will provide evidence for stakeholders regarding the expected effect size associated with the intervention. This review will also present the BCTs used in the available studies. Thus, this review will provide evidence for considering PA intervention incorporating smartphone application and considering the inclusion of BCT components in smartphone applications for promoting PA among university students. If our meta-analyses will result in positive effects, this review will support the inclusion of smartphone application in PA intervention as a novel strategy to reduce the problems of physical inactivity among university students which have not change in recent years [43, 44, 45, 46].

Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Bull FC, the Expert Working Groups. Physical Activity Guidelines in the U.K.: Review and Recommendations. Loughborough: School of Sport, Exercise and Health Sciences; 2010

2. Saint-Maurice PF, Coughlan D, Kelly SP, et al. Association of leisure-time physical activity across the adult life course with all-cause and cause-specific mortality. JAMA Netw Open. 2019;2(3):e190355

3. Hagströmer M, Franzén E. The importance of physical activity and health for physical therapy. Phys Ther Rev. 2017;22(3-4):116-123.

4. World Health Organization. Global Recommendations on Physical Activity for Health. Geneva: World Health Organization; 2010

5. Tudor-Locke C, Craig C, Brown W, Clemes S, De Cocker K, Giles-Corti B et al. How many steps/day are enough? for adults. Int J Behav Nutr Phys Act. 2011;8(1):79.

6. IPAQ Research Committee. Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ) – Short and Long Forms. 2005.

7. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017; 14(1), 75.

8. World Health Organization. Global health risks : mortality and burden of disease attributable to selected major risks. Geneva: World Health Organization; 2009

9. World Health Organization. Prevalence of insufficient physical activity among adults.

Geneva: World Health Organization; 2016

10. Keating X, Guan , Piñero J, et al. A meta-analysis of college students' physical activity behaviors. J Am Coll Health. 2005;54(2), 116-126.

11. Carney C, Mutrie N, Mcneish, S. The impact of transition from university on physically active students. Int J Health Promot Educ. 2000; 38(3), 113-118.

12. Newzoo | Games & Esports Analytics and Market Research [Internet]. San Fransisco: Newzoo. Newzoo's 2018 Global Mobile Market Report: Insights into the World's 3 Billion Smartphone Users; 2018 Sep 11 [cited 2019 Apr 05]; Available from: https://newzoo.com/insights/articles/newzoos-2018-global-mobile-market-report-%20insights-into-the-worlds-3-billion-smartphone-users/

13. Statista - The Statistics Portal for Market Data, Market Research and Market Studies [Internet]. Hamburg: Statista. Number of mobile app hours per smartphone and tablet app user in the United States in June 2016, by age group; 2016 Sep 13 [cited 2019 Apr 05]; Available from: https://www.statista.com/statistics/323522/us-user-mobile-app-engagement-age/

14. Statistics Canada: Canada's national statistical agency [Internet]. Ottawa: StatCan. Trends in the Age Composition of College and University Students and Graduates; 2010 Dec 13 [cited 2019 Apr 05]; Available from: https://www150.statcan.gc.ca/n1/pub/81-004-x/2010005/article/11386-eng.htm

15. Middelweerd A, Mollee J, Van Der Wal C, et al. Apps to promote physical activity among adults: a review and content analysis. Int J Behav Nutr Phys Act. 2014;11(1), 97.

16. Berry A, McCabe C, Muir S, Walsh N. Digital behaviour change interventions to facilitate physical activity in osteoarthritis: a systematic review. Phys Ther Rev. 2018;23(3):197-206.

17. Bird E, Baker G, Mutrie N, Ogilvie D, Sahlqvist S, Powell J. Behavior change techniques used to promote walking and cycling: a systematic review. Health Psychol. 2013;32(8):829-838.

18. Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective techniques in healthy eating and physical activity interventions: a meta-regression. Health Psychol. 2009;28(6):690-701.

19. Murray J, Brennan S, French D, Patterson C, Kee F, Hunter R. Effectiveness of physical activity interventions in achieving behaviour change maintenance in young and middle aged adults: a systematic review and meta-analysis. Social Science & Medicine. 2017;192:125-133.

20. Direito A, Pfaeffli Dale L, Shields E, et al. Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? BMC Public Health. 2014;14(1), 646.

21. Bort-Roig J, Gilson N, Puig-Ribera D, et al. Measuring and influencing physical activity with smartphone technology: a systematic review. Sports Med. 2014;44(5), 671-686.

22. Coughlin SS, Whitehead M, Sheat, JQ, et al. A review of smartphone applications for promoting physical activity. Jacobs J Community Med. 2016;2(1), 021.

23. Gal R, May A, Van Overmeeren M, et al. The effect of physical activity interventions

comprising wearables and smartphone applications on physical activity: a systematic review and meta-analysis. Sports Med Open. 2018;4(1), 1-15.

24. Howlett N, Trivedi D, Troop N, et al. Are physical activity interventions for healthy inactive adults effective in promoting behavior change and maintenance, and which behavior change techniques are effective? a systematic review and meta-analysis. Transl Behav Med. 2019; 9(1), 147-157.

25. Romeo A, Edney S, Plotnikoff R, et al. Can smartphone apps increase physical activity? a systematic review and meta-analysis (Preprint). J Med Internet Res. 2018; 08/28/2018.

26. Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ. 2008;:a1655.

27. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015;349(Jan02 1), G7647.

28. Eysenbach G, CONSORT-EHEALTH Group. CONSORT-EHEALTH: improving and standardizing evaluation reports of web-based and mobile health interventions. J Med Internet Res. 2011;13(4):e126

29. Michie S, Richardson M, Johnston M, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med. 2013;46(1), 81-95.

30. Higgins JP, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for

assessing risk of bias in randomised trials. BMJ. 2011 Oct 18;343:d5928.

31. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016 Oct 12;355:i4919.

32. Thomas J, Nelson J, Silverman S. Research methods in physical activity (Sixth ed.). Champaign, Ill.: Human Kinetics; 2011

33. Kelly P, Kahlmeier S, Götschi T, et al. Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. Int J Behav Nutr Phys Act. 2014 Oct 24;11:132.

34. Marshall S, Levy S, Tudor-Locke C, et al. Translating physical activity recommendations into a pedometer-based step goal. Am J Prev Med. 2009;36(5), 410-415.

35. Wahid A, Manek N, Nichols M, et al. Quantifying the association between physical activity and cardiovascular disease and diabetes: a systematic review and meta-analysis. J Am Heart Assoc. 2016 Sep 14;5(9):e002495.

36. Higgins J, Green, S. Cochrane handbook for systematic reviews of interventions (Cochrane book series). Chichester, England ; Hoboken, NJ: Wiley- Blackwell; 2008

37. Cohen J. Statistical Power Analysis for the Behavioral Sciences. New York, NY: Routledge Academic; 1988

38. Teixeira PJ, Silva MN, Mata J, et al. Motivation, self-determination, and long-term weight control. Int J Behav Nutr Phys Act. 2012;9, 22.

39. van Uffelen JGZ, Khan A, Burton NW. Gender differences in physical activity

motivators and context preferences: a population-based study in people in their sixties. BMC Public Health. 2017 Jul 4;17(1):624.

40. Kitsiou S, Paré G, Jaana M, Gerber B. Effectiveness of mHealth interventions for patients with diabetes: an overview of systematic reviews. PLOS ONE. 2017;12(3):e0173160.

41. Marcolino M, Oliveira J, D'Agostino M, Ribeiro A, Alkmim M, Novillo-Ortiz D. The impact of mhealth interventions: systematic review of systematic reviews. JMIR Mhealth Uhealth. 2018;6(1):e23.

42. Kondric M, Sindik J, Furjan-Mandic G, & Schiefler, B. Participation motivation and student's physical activity among sport students in three countries. J Sports Sci Med. 2013;12(1), 10–18.

43. Al-Hazzaa H, Alzamil H, Alhakbany M, Alfadda N, Almusallam S. A profile of physical activity, sedentary behaviors, sleep, and dietary habits of Saudi college female students. J Family Community Med. 2019;26(1):1.

44. Murphy J, MacDonncha C, Murphy M, Murphy N, Timperio A, Leech R et al. Identification of health-related behavioural clusters and their association with demographic characteristics in Irish university students. BMC Public Health. 2019;19(1).

45. Štefan L, Sporiš G, Krističević T, Knjaz D. Associations between sleep quality and its domains and insufficient physical activity in a large sample of Croatian young adults: a cross-sectional study. BMJ Open. 2018;8(7):e021902.

46. Uddin R, Khan A, Burton N. Prevalence and sociodemographic patterns of physical

422 activity among Bangladeshi young adults. J Health Popul Nutr. 2017;36(1).

423

Appendix – Medline(OVID) Search Strategy

This is the search strategy for Medline(OVID) database that will be adapted to fit the other 15 databases. The exact search for each of the databases will be available on request from the corresponding author.

Concept 1: Randomized Controlled Trial and Quasi-Experimental

1. Randomized Controlled Trials as Topic/

2. randomized controlled trial/

3. Random Allocation/

4. Double Blind Method/

5. Single Blind Method/

6. clinical trial/

7. clinical trial, phase i.pt.

8. clinical trial, phase ii.pt.

9. clinical trial, phase iii.pt.

10. clinical trial, phase iv.pt.

11. controlled clinical trial.pt.

12. randomized controlled trial.pt.

13. multicenter study.pt.

14. clinical trial.pt.

15. exp Clinical Trials as topic/

16. or/1-15

17. (clinical adj trial$).tw.

18. ((singl$ or doubl$ or treb$ or tripl$) adj (blind$3 or mask$3)).tw.

19. PLACEBOS/

20. placebo$.tw.

21. randomly allocated.tw.

22. (allocated adj2 random$).tw.

23. or/17-22

24. 16 or 23

25. case report.tw.

26. letter/

27. historical article/

28. or/25-27

29. 24 not 28

Concept 2: Population – University students / Young adults

30. exp Young Adult/

31. exp Universities/

32. education, dental/ or exp education, medical/ or exp education, medical, continuing/ or exp education, medical, graduate/ or exp education, medical, undergraduate/ or exp teaching rounds/ or exp education, nursing/ or exp education, pharmacy/ or exp education, public health professional/

33. exp students, health occupations/ or exp students, dental/ or exp students, medical/ or exp students, nursing/ or exp students, pharmacy/ or exp students, premedical/ or exp students, public health/

34. (universit* or college or young male* or young female* or freshman or undergraduate* or higher education or tertiary education or medical student* or nursing student* or dental student* or pharmacy student*).ti,ab.

35. 30 or 31 or 32 or 33 or 34

Concept 3: Outcome – Physical Activity

36. exp Exercise/

37. exp Physical Exertion/

38. exp Physical Fitness/

39. exp Sports/

40. exp Weight Loss/

41. (physical activit* or exercise* or active living or active lifestyle or walk* or cycling or running or active transport* or leisure activit* or fitness or weight loss or weight*loss or weight reduction or weight maintenance or maintaining weight or weight management or pedometer or accelerometer or IPAQ or GPAQ).ti,ab.

42. 36 or 37 or 38 or 39 or 40 or 41

Concept 4: Intervention – Smartphone applications

43. exp Telemedicine/

44. exp Smartphone/

45. exp Cell Phone/

46. exp Mobile Applications/

47. exp Video Games/

48. (smart phone* or smartphone* or smart-phone* or cell*phone* or cell-phone* or mobile phone* or mobile-phone or mobile device or mobile telephone* or i*Phone* or android* or iOS or mobile health or mhealth or m-health or app or apps or mobile application* or exergam* or gamification* or wearable).ti,ab.

49. exp Wearable Electronic Devices/

50. 43 or 44 or 45 or 46 or 47 or 48 or 49

Combined

51. 29 and 35 and 42 and 50

Search results were limited to year of publication from 2007 to present since the first smartphone was launched in 2007.

52. limit 51 to yr="2007 -Current"

502 Table 1. List of databases

No	Database
1	Cochrane Central Register of Controlled Trials (CENTRAL)
2	MEDLINE (Ovid)
3	Embase (Ovid)
4	The Cumulative Index to Nursing and Allied Health Literature (CINAHL) (EBSCO)
5	Web of Science (Clarivate)
6	Scopus (Elsevier)
7	PsycINFO (Ovid)
8	SPORTDiscus (EBSCO)
9	SCISearch
10	ACM Digital Library
11	IEEE Xplore Digital Library
12	Pubmed
13	OpenGrey
14	GreySource
15	The Grey Literature Report
16	Proquest Dissertations

503

504 Table 2. Data extraction table

Categories	Extraction Items
General	Author(s); title; funding source(s)
Method	Design: objectives of the study; target behavior(s); duration of the study; study location; recruitment setting, date of study
	Participants: population characteristics, inclusion and exclusion criteria; number of participants; age, gender, weight status, socio-demographic information
Intervention	Frequency and length of sessions; intervention duration; intervention setting; intervention provider; access of the application; behavioral change techniques; mode of delivery, components of the intervention; theoretical framework, the use of prompts/reminders, co-interventions
Outcomes	Measurement unit; Measurement type; measurement tool; follow-up duration and frequency; mean and standard deviation at baseline, post-intervention, and follow up; effect size; attrition rate/diagram; participants' perception of interventions, engagement and usage rates of the app

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The Effect of Smartphone Application Interventions on Physical Activity Level Among University/College Students: A Systematic Review Protocol

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The Effect of Smartphone Application Intervention on Physical Activity Level Among University/College Students: A Systematic Review Protocol

Introduction: Strong evidence has shown the benefits of engagement in recommended amount of physical activity. However, it is estimated that nearly half of university students do not participate in sufficient amount of physical activity. While entering university life is a transitional stage important for adopting a particular lifestyle, it is crucial to develop and implement novel strategies to promote physical activity among this population. A smartphone application is a potential media for delivering physical activity intervention. However, recent reviews in this area have demonstrated high levels of heterogeneity, potentially due to population diversity. To date there has been no attempt to synthesize the literature assessing the effectiveness of this particular intervention in university students.

Aim: The primary aim of this review is to investigate the effectiveness of smartphone application intervention on physical activity level among university students. The secondary aim is examining the behavior change technique elements of smartphone applications used in available studies.

Methods: Sixteen electronic databases will be searched for randomized controlled trials and quasi-experimental studies reporting the effect of smartphone application intervention on physical activity outcomes among university students. Two reviewers will independently screen the potential studies and extract data from included studies. Active elements of smartphone applications used in included studies will be coded using the Behavior Change Technique taxonomy v1. Risk of bias and quality of evidence of individual studies will be assessed. The overall evidence will be presented in a narrative synthesis and quantitative synthesis.

Keywords: exercise; m-health; physical activity; smartphone applications; university students

Introduction

Several studies have shown the health benefits of sufficient levels of physical activity (PA) for people of all ages [1,2]. They have demonstrated the role of PA in both prevention and treatment of several non-communicable diseases, such as coronary heart disease, hypertension, stroke, certain cancers, as well as mental health disorders such as depression and anxiety. Since maintaining and restoring functional ability throughout the lifespan are the aims of physical therapy, physical activity is an important aspect of physical therapy [3]. The World Health Organization [4] recommends that adults should engage in at least 150 minutes of moderate-intensity PA or 75 minutes of vigorous-intensity PA throughout the week which could be accumulated from at least 10 minutes bouts of PA. This amount is equivalent to 7000 steps/day [5] or 600 MET.minutes/week [6].

Performing an insufficient amount of PA is referred to as physical inactivity [7]. Nowadays, physical inactivity becomes the fourth leading risk factor of mortality [8]. Almost one in three adults are not meeting the minimum recommendation for PA [9]. The problems of physical inactivity are striking among university students. Nearly 50% of university students are physically inactive [10]. Entering a university is considered as a transitional life stage when students begin to make their own decision for adopting a lifestyle in later life [11]. Thus, it is crucial to develop and implement novel strategies to promote PA among university students.

A smartphone could be leveraged as a communication channel for delivering PA intervention to university students. The number of smartphone users is rapidly growing, which was projected to reach 48% of adults by 2021 [12]. According to Statista [13], young adults have the highest engagement to smartphone applications among all age

group. Since over than 75% of university students are young adults aged 17-27 years [14], a smartphone application could get high engagement from this population.

Smartphone applications promoting physical activity are software developed for consumer mobile electronic devices, such as smartphones and tablets, which aim to motivate PA behavior. These applications, including fitness-specific applications, gaming applications, or social media applications, could provide individually tailored PA intervention containing behavior change techniques (BCTs) [15]. The applications could promote PA behavior since they could contain BCTs which were associated with PA intervention effectiveness, such as a combination of self-monitoring and goal setting, feedback on performance, or other behavior change techniques from control-theory [16, 17, 18, 19, 20].

Previous literature reviews provide evidence of promising results of smartphone applications for promoting PA behavior [21, 22, 23, 24, 25]. Evidence from non-randomized controlled trials found that smartphone apps could either increase PA, decrease PA, or prevent PA decline [21]. Romeo et al. [25] conducted a subgroup analysis on healthy adult across all ages that resulted in a small, inconclusive and high heterogeneous result (mean difference= +649,54 steps per day, 95% CI -822.66 to 21221.74, I^2 80%). Heterogeneous and inconclusive results from previous systematic reviews could be attributable, in part, to various population.

To date, there has been no attempt to synthesize the literature assessing the effectiveness of this particular intervention in university students. Craig et al. [26] suggested that identifying the BCT component of complex intervention, including physical activity intervention, could help in understanding the effectiveness of the intervention. However, there has been no attempt to describe BCTs utilized in the available studies of PA intervention incorporating smartphone applications.

Aims of review

This systematic review will investigate the effectiveness of PA intervention utilizing smartphone applications among university students. In addition, the secondary aim of this review is examining the behavior change techniques (BCTs) used in available studies.

Methods

This systematic review protocol has been reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines [27] and has been registered in the International Prospective Registers of Systematic Reviews (PROSPERO) (registration number CRD42019137417).

Eligibility criteria

Participants

Studies will be eligible for inclusion if they were conducted in healthy university students, or young adults aged 18-35 years old with tertiary education level. Studies with participants characterized by intellectual or marked cognitive impairments or with a severe mobility disorder and chronic diseases, or trained athletes will be excluded. Studies recruiting university staff or other general populations will be considered to be included if their average age was in young adult age range (considered as 18-35 years) and more than 70% of their participants were university students, or they presented results of sub-group analysis allowing data from university students to be extracted. Primary reviewer will contact the author(s) of potential studies if they did not provide a clear proportion of university students or if they could provide the subgroup analysis on university students. Only studies measuring PA at an individual level will be included.

Intervention

Studies incorporating smartphone applications as an intervention targeting either physical activity as a single target behavior or physical activity as a part of multiple target behavior will be included. Short text message application or web-based intervention will be excluded since smartphone apps could contain more comprehensive and interactive components [20].

Comparator

For inclusion in the review, studies had to compare physical activity intervention incorporating smartphone application to other kinds of physical activity intervention, including usual care such as physical activity promotion brochure, or to studies incorporating smartphone app which do not have a physical activity component, or to conditions without any intervention such as waiting-list control.

Outcome measures

Primary outcomes: Studies that either objectively or subjectively assess change between baseline and follow-up for PA level will be included. PA level could be expressed as an estimate of total energy expenditure (kcal/kg/week or kcal/week or MET.minutes/week), minutes completed or energy expensed at a moderate-vigorous physical activity (MVPA), the number of steps, or walking distance.

Secondary outcomes: As suggested by the CONSORT-EHEALTH checklist [28], the secondary outcomes of this review will include data relevant to participants' perception of interventions, engagement and usage rates of the app if possible.

Information sources and search strategy

A systematic search will be conducted on 16 electronic databases (Table 1); by two independent reviewers. In brief, the search strategy will combine indexed terms and free terms for the population ([{university OR college OR first-year OR university-age OR college-age OR higher education OR post-secondary OR tertiary education OR medical OR dentist OR nursing OR pharmacist} AND {age OR year OR student*] OR young adult), intervention ([physical activity OR PA education OR health education OR PA Promotion OR physical education OR health promotion OR exercise OR weight loss } AND {smartphone OR assess OR smart-phone OR mobile phone OR mobile device OR cell phone OR mobile OR m-health OR android OR iPhone OR app OR application OR digital).

We will also search for current and ongoing trials such as the World Health Organization – International Clinical Trials Registry Platform (WHO ITCRP) and ClinicalTrials.gov. Then, we will contact the authors for any unpublished results.

We will amend the search strategy used for MEDLINE (OVID) where necessary to search the other databases listed (Appendix 1). We will apply no language restriction to the searches. However, articles which were published in non-English language should have abstracts or titles in English. We will include such studies with English abstracts into the analysis if they can be easily translated into English using Google Translate. Studies with English headings or abstracts, but that cannot be translated into English, will remain as appendices.

Reference lists and links from PubMed of all primary studies and review articles will be checked for additional references. We will contact authors of identified primary studies for other published and unpublished studies which meet the review inclusion criteria as well as ongoing trials and relevant publications in press.

Data management

Having conducted the search strategy described above, the primary authors (RAW) will import the results from all literature searches into Endnote software and will remove duplicates using the software and manually remove any other duplicates.

Selection process

From scoping searches, several thousand citations are expected to be identified with the initial search strategy. The primary author (RAW) and second author (BN) will independently screen these titles and abstracts manually to exclude studies which do not meet the inclusion criteria. They will then screen the full-text of those studies to identify a final set of eligible studies. The second author (BN) will screen at least 10% of the potential studies. RAW and BN will also identify and record reasons for exclusion of the excluded studies. They will resolve any disagreements through discussion with involvement from a third author (GB) if required. The primary author (RAW) will record the selection process to complete a PRISMA flow diagram and "Characteristics of excluded studies" table.

Data extraction

Two authors (RAW and BN) will independently extract the following study characteristics (Table 2) from included studies according to the Consolidated Standards of Reporting Trials-EHEALTH (CONSORT-EHEALTH) checklist [28] into Excel using a data extraction form.

Data items

Two authors (RAW and BN) will independently code and extract items, except behavior change techniques (BCTs), using the following categories (Table 2).

Two authors (RAW and GB) will identify and code BCTs for all interventions using the BCT Taxonomy v1 [29]. This taxonomy was developed to help researchers in precisely characterizing and reporting the active contents of a behavior change intervention [29]. Containing 93 BCTs clustered into 16 groups, this taxonomy could be used to specify interventions [29]. The included studies which did not report outcome data in a useable way will be noted in the "Characteristics of included studies" table.

Risk of bias in individual studies

Two authors (RAW and GB) will assess the risk of bias for all eligible studies using the Cochrane Collaboration's tool for assessing the risk of bias in primary RCTs [30] and the Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I) tools for assessing the risk of bias in primary Quasi-Experimental studies [31]. The author will present a "Risk of bias" table for each study.

We will assess the primary RCT studies based on the quality of the random sequence generation, allocation concealment, blinding of outcome assessment, completeness of data and handling of incomplete data, the presence of reporting bias and other potential sources of bias including the validity of outcome measures, intention-to-treat analysis approach and comparability of groups at baseline [30,32]. We will not assess the primary RCT studies on whether participants and personnel were blinded to their group allocation since this would not be appropriate for a physical activity intervention study. We will rate each domain in the Cochrane Risk of Bias tool as "high" or "low" risk of bias if sufficient information is available. If there is a lack of information, we will rate the domain as "unclear."

We will assess quasi-experimental studies using ROBINS-I tool based on seven domains: bias due to confounding, bias in selection of participants into the study, misclassification bias, performance bias, attrition bias, detection bias, and reporting bias

[31]. We will rate each domain in the ROBINS-I tool as "Low," "Moderate," "Serious," or "Critical" risk of bias if sufficient information is available. If there is a lack of information on whether bias might be present in a domain, we will rate it as "No information."

Measures of treatment effect

For each study with dichotomous outcomes such as outcome categorized by the achievement of the recommended level of PA, we will calculate the effect size using an odds ratio (OR) and confidence interval (CI). For each study with continuous outcomes such as average energy expenditure, we will calculate the effect size using the mean difference (MD) if same measurement scale was used across the studies, and the standardized mean difference (SMD) if different measurement scale was used across the studies. We will interpret the treatment effect using a threshold of 675 MET.minutes/week or 3278 steps/day as minimally important difference for physical activity outcome [33, 34, 35].

Dealing with missing data

Primary author (RAW) will contact the original investigator of potentially included studies to request missing or unclear data. Missing data will be captured in the data extraction form and reported in the "Risk of bias" table. We will utilize the outcome from the longest period of follow up if an included study reported an outcome measure at more than one-time point.

Assessment of heterogeneity

We will assess the heterogeneity by examining the forest plot and calculating I^2 with upper limits of 25, 50, and 75 for low, moderate, and high heterogeneity, respectively

[36].

Assessment of reporting bias

We will present a funnel plot to assess reporting bias if there are sufficient eligible studies (10 or more).

Data synthesis

First, the primary author (RAW) will present a narrative summary of the study results in PA outcome structured around the type of the comparator, the type of the outcomes, and the type of BCTs used. Then, we will conduct meta-analyses to generate an average mean change in PA from the pooling of studies. We will utilize a random-effect model to anticipate study heterogeneity because of the high variance of intervention designs. If appropriate, the outcome meta-analyzed in this review will be the mean change in PA level either reported as time spent in total PA or MVPA, total energy expenditure, step count, or walking distance. The mean difference (MD) will be calculated when the same measurement scale was used across the eligible studies. On the other hand, we will calculate the standardized mean difference (SMD) when different measurement scale was used across the eligible studies. The SMD will be interpreted using thresholds of 0.2, 0.5, and 0.8 as a small effect size, medium effect size, and large effect size, respectively, as suggested by Cohen [37].

Subgroup and sensitivity analysis

We will perform subgroup analyses where appropriate and possible, to compare studies that target single versus multiple behavior, RCTs versus quasi-experimental studies, studies in healthy weight versus overweight [38], studies comparing smartphone apps intervention with other kinds of intervention versus studies comparing smartphone apps

intervention with no intervention, studies with duration of 6 months or below versus longer than 6 months, and studies in male versus female [39].

We will perform a sensitivity analysis for studies that included university staffs, postgraduate students, Ph.D. students or young adults with low education level versus studies that only include undergraduate students because the age of participants and education level could influence the effectiveness of m-health intervention [40, 41]. We will also exclude studies delivering smartphone intervention with co-intervention in sensitivity analyses to isolate the effectiveness of smartphone intervention as a single intervention. Studies delivering intervention specifically for sports students will also be excluded in sensitivity analyses since sports students could have different motivation in sport participation than students in other faculties [42]. We will also conduct sensitivity analysis to assess the robustness of meta-analytic for study with a low risk of bias by conducting a meta-analysis with all eligible studies and another analysis which excludes studies with a high risk of bias.

Confidence in cumulative evidence

We will assess the quality of evidence for primary outcomes using the Grading of Recommendation, Assessment, Development and Evaluation (GRADE) approach [36].

Discussion

University students represent an important population to target for PA intervention because this age group typically do not meet physical activity guidelines [10]. Furthermore, the transition to university represents a critical period for adopting a particular lifestyle [11]. As far as we are aware, there has been no attempt to synthesize the literature exclusively assessing the effect of smartphone applications on physical activity level among university students. This review will be the first to evaluate the

effectiveness of physical activity intervention incorporating smartphone application in populations of university students. If there are sufficient homogenous data to conduct meta-analyses, this review will provide evidence for stakeholders regarding the expected effect size associated with the intervention. This review will also present the BCTs used in the available studies. Thus, this review will provide evidence for considering PA intervention incorporating smartphone application and considering the inclusion of BCT components in smartphone applications for promoting PA among university students. If our meta-analyses will result in positive effects, this review will support the inclusion of smartphone application in PA intervention as a novel strategy to reduce the problems of physical inactivity among university students which have not change in recent years [43, 44, 45, 46].

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Bull FC, the Expert Working Groups. Physical Activity Guidelines in the U.K.: Review and Recommendations. Loughborough: School of Sport, Exercise and Health Sciences; 2010

2. Saint-Maurice PF, Coughlan D, Kelly SP, et al. Association of leisure-time physical activity across the adult life course with all-cause and cause-specific mortality. JAMA Netw Open. 2019;2(3):e190355

3. Hagströmer M, Franzén E. The importance of physical activity and health for physical therapy. Phys Ther Rev. 2017;22(3-4):116-123.

4. World Health Organization. Global Recommendations on Physical Activity for Health. Geneva: World Health Organization; 2010

5. Tudor-Locke C, Craig C, Brown W, Clemes S, De Cocker K, Giles-Corti B et al. How many steps/day are enough? for adults. Int J Behav Nutr Phys Act. 2011;8(1):79.

6. IPAQ Research Committee. Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ) – Short and Long Forms. 2005.

7. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017; 14(1), 75.

8. World Health Organization. Global health risks : mortality and burden of disease attributable to selected major risks. Geneva: World Health Organization; 2009

9. World Health Organization. Prevalence of insufficient physical activity among adults.

Geneva: World Health Organization; 2016

10. Keating X, Guan , Piñero J, et al. A meta-analysis of college students' physical activity behaviors. J Am Coll Health. 2005;54(2), 116-126.

11. Carney C, Mutrie N, Mcneish, S. The impact of transition from university on physically active students. Int J Health Promot Educ. 2000; 38(3), 113-118.

12. Newzoo | Games & Esports Analytics and Market Research [Internet]. San Fransisco: Newzoo. Newzoo's 2018 Global Mobile Market Report: Insights into the World's 3 Billion Smartphone Users; 2018 Sep 11 [cited 2019 Apr 05]; Available from: https://newzoo.com/insights/articles/newzoos-2018-global-mobile-market-report-%20insights-into-the-worlds-3-billion-smartphone-users/

13. Statista - The Statistics Portal for Market Data, Market Research and Market Studies [Internet]. Hamburg: Statista. Number of mobile app hours per smartphone and tablet app user in the United States in June 2016, by age group; 2016 Sep 13 [cited 2019 Apr 05]; Available from: https://www.statista.com/statistics/323522/us-user-mobile-app-engagement-age/

14. Statistics Canada: Canada's national statistical agency [Internet]. Ottawa: StatCan. Trends in the Age Composition of College and University Students and Graduates; 2010 Dec 13 [cited 2019 Apr 05]; Available from: https://www150.statcan.gc.ca/n1/pub/81-004-x/2010005/article/11386-eng.htm

15. Middelweerd A, Mollee J, Van Der Wal C, et al. Apps to promote physical activity among adults: a review and content analysis. Int J Behav Nutr Phys Act. 2014;11(1), 97.

16. Berry A, McCabe C, Muir S, Walsh N. Digital behaviour change interventions to facilitate physical activity in osteoarthritis: a systematic review. Phys Ther Rev. 2018;23(3):197-206.

17. Bird E, Baker G, Mutrie N, Ogilvie D, Sahlqvist S, Powell J. Behavior change techniques used to promote walking and cycling: a systematic review. Health Psychol. 2013;32(8):829-838.

18. Michie S, Abraham C, Whittington C, McAteer J, Gupta S. Effective techniques in healthy eating and physical activity interventions: a meta-regression. Health Psychol. 2009;28(6):690-701.

19. Murray J, Brennan S, French D, Patterson C, Kee F, Hunter R. Effectiveness of physical activity interventions in achieving behaviour change maintenance in young and middle aged adults: a systematic review and meta-analysis. Social Science & Medicine. 2017;192:125-133.

20. Direito A, Pfaeffli Dale L, Shields E, et al. Do physical activity and dietary smartphone applications incorporate evidence-based behaviour change techniques? BMC Public Health. 2014;14(1), 646.

21. Bort-Roig J, Gilson N, Puig-Ribera D, et al. Measuring and influencing physical activity with smartphone technology: a systematic review. Sports Med. 2014;44(5), 671-686.

22. Coughlin SS, Whitehead M, Sheat, JQ, et al. A review of smartphone applications for promoting physical activity. Jacobs J Community Med. 2016;2(1), 021.

23. Gal R, May A, Van Overmeeren M, et al. The effect of physical activity interventions

comprising wearables and smartphone applications on physical activity: a systematic review and meta-analysis. Sports Med Open. 2018;4(1), 1-15.

24. Howlett N, Trivedi D, Troop N, et al. Are physical activity interventions for healthy inactive adults effective in promoting behavior change and maintenance, and which behavior change techniques are effective? a systematic review and meta-analysis. Transl Behav Med. 2019; 9(1), 147-157.

25. Romeo A, Edney S, Plotnikoff R, et al. Can smartphone apps increase physical activity? a systematic review and meta-analysis (Preprint). J Med Internet Res. 2018; 08/28/2018.

26. Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ. 2008;:a1655.

27. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015;349(Jan02 1), G7647.

28. Eysenbach G, CONSORT-EHEALTH Group. CONSORT-EHEALTH: improving and standardizing evaluation reports of web-based and mobile health interventions. J Med Internet Res. 2011;13(4):e126

29. Michie S, Richardson M, Johnston M, et al. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med. 2013;46(1), 81-95.

30. Higgins JP, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for

assessing risk of bias in randomised trials. BMJ. 2011 Oct 18;343:d5928.

31. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016 Oct 12;355:i4919.

32. Thomas J, Nelson J, Silverman S. Research methods in physical activity (Sixth ed.). Champaign, Ill.: Human Kinetics; 2011

33. Kelly P, Kahlmeier S, Götschi T, et al. Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. Int J Behav Nutr Phys Act. 2014 Oct 24;11:132.

34. Marshall S, Levy S, Tudor-Locke C, et al. Translating physical activity recommendations into a pedometer-based step goal. Am J Prev Med. 2009;36(5), 410-415.

35. Wahid A, Manek N, Nichols M, et al. Quantifying the association between physical activity and cardiovascular disease and diabetes: a systematic review and meta-analysis. J Am Heart Assoc. 2016 Sep 14;5(9):e002495.

36. Higgins J, Green, S. Cochrane handbook for systematic reviews of interventions (Cochrane book series). Chichester, England ; Hoboken, NJ: Wiley- Blackwell; 2008

37. Cohen J. Statistical Power Analysis for the Behavioral Sciences. New York, NY: Routledge Academic; 1988

38. Teixeira PJ, Silva MN, Mata J, et al. Motivation, self-determination, and long-term weight control. Int J Behav Nutr Phys Act. 2012;9, 22.

39. van Uffelen JGZ, Khan A, Burton NW. Gender differences in physical activity

motivators and context preferences: a population-based study in people in their sixties. BMC Public Health. 2017 Jul 4;17(1):624.

40. Kitsiou S, Paré G, Jaana M, Gerber B. Effectiveness of mHealth interventions for patients with diabetes: an overview of systematic reviews. PLOS ONE. 2017;12(3):e0173160.

41. Marcolino M, Oliveira J, D'Agostino M, Ribeiro A, Alkmim M, Novillo-Ortiz D. The impact of mhealth interventions: systematic review of systematic reviews. JMIR Mhealth Uhealth. 2018;6(1):e23.

42. Kondric M, Sindik J, Furjan-Mandic G, & Schiefler, B. Participation motivation and student's physical activity among sport students in three countries. J Sports Sci Med. 2013;12(1), 10–18.

43. Al-Hazzaa H, Alzamil H, Alhakbany M, Alfadda N, Almusallam S. A profile of physical activity, sedentary behaviors, sleep, and dietary habits of Saudi college female students. J Family Community Med. 2019;26(1):1.

44. Murphy J, MacDonncha C, Murphy M, Murphy N, Timperio A, Leech R et al. Identification of health-related behavioural clusters and their association with demographic characteristics in Irish university students. BMC Public Health. 2019;19(1).

45. Štefan L, Sporiš G, Krističević T, Knjaz D. Associations between sleep quality and its domains and insufficient physical activity in a large sample of Croatian young adults: a cross-sectional study. BMJ Open. 2018;8(7):e021902.

46. Uddin R, Khan A, Burton N. Prevalence and sociodemographic patterns of physical

activity among Bangladeshi young adults. J Health Popul Nutr. 2017;36(1).

Appendix – Medline(OVID) Search Strategy

This is the search strategy for Medline(OVID) database that will be adapted to fit the other 15 databases. The exact search for each of the databases will be available on request from the corresponding author.

Concept 1: Randomized Controlled Trial and Quasi-Experimental

1. Randomized Controlled Trials as Topic/

2. randomized controlled trial/

3. Random Allocation/

4. Double Blind Method/

5. Single Blind Method/

6. clinical trial/

7. clinical trial, phase i.pt.

8. clinical trial, phase ii.pt.

9. clinical trial, phase iii.pt.

10. clinical trial, phase iv.pt.

11. controlled clinical trial.pt.

12. randomized controlled trial.pt.

13. multicenter study.pt.

14. clinical trial.pt.

15. exp Clinical Trials as topic/

16. or/1-15

17. (clinical adj trial$).tw.

18. ((singl$ or doubl$ or treb$ or tripl$) adj (blind$3 or mask$3)).tw.

19. PLACEBOS/

20. placebo$.tw.

21. randomly allocated.tw.

22. (allocated adj2 random$).tw.

23. or/17-22

24. 16 or 23

25. case report.tw.

26. letter/

27. historical article/

28. or/25-27

29. 24 not 28

Concept 2: Population – University students / Young adults

30. exp Young Adult/

31. exp Universities/

32. education, dental/ or exp education, medical/ or exp education, medical, continuing/ or exp education, medical, graduate/ or exp education, medical, undergraduate/ or exp teaching rounds/ or exp education, nursing/ or exp education, pharmacy/ or exp education, public health professional/

33. exp students, health occupations/ or exp students, dental/ or exp students, medical/ or exp students, nursing/ or exp students, pharmacy/ or exp students, premedical/ or exp students, public health/

34. (universit* or college or young male* or young female* or freshman or undergraduate* or higher education or tertiary education or medical student* or nursing student* or dental student* or pharmacy student*).ti,ab.

35. 30 or 31 or 32 or 33 or 34

Concept 3: Outcome – Physical Activity

36. exp Exercise/

37. exp Physical Exertion/

38. exp Physical Fitness/

39. exp Sports/

40. exp Weight Loss/

41. (physical activit* or exercise* or active living or active lifestyle or walk* or cycling or running or active transport* or leisure activit* or fitness or weight loss or weight*loss or weight reduction or weight maintenance or maintaining weight or weight management or pedometer or accelerometer or IPAQ or GPAQ).ti,ab.

42. 36 or 37 or 38 or 39 or 40 or 41

Concept 4: Intervention – Smartphone applications

43. exp Telemedicine/

44. exp Smartphone/

45. exp Cell Phone/

46. exp Mobile Applications/

47. exp Video Games/

48. (smart phone* or smartphone* or smart-phone* or cell*phone* or cell-phone* or mobile phone* or mobile-phone or mobile device or mobile telephone* or i*Phone* or android* or iOS or mobile health or mhealth or m-health or app or apps or mobile application* or exergam* or gamification* or wearable).ti,ab.

49. exp Wearable Electronic Devices/

50. 43 or 44 or 45 or 46 or 47 or 48 or 49

Combined

51. 29 and 35 and 42 and 50

Search results were limited to year of publication from 2007 to present since the first smartphone was launched in 2007.

52. limit 51 to yr="2007 -Current"

530 Table 1. List of databases

No	Database
1	Cochrane Central Register of Controlled Trials (CENTRAL)
2	MEDLINE (Ovid)
3	Embase (Ovid)
4	The Cumulative Index to Nursing and Allied Health Literature (CINAHL) (EBSCO)
5	Web of Science (Clarivate)
6	Scopus (Elsevier)
7	PsycINFO (Ovid)
8	SPORTDiscus (EBSCO)
9	SCISearch
10	ACM Digital Library
11	IEEE Xplore Digital Library
12	Pubmed
13	OpenGrey
14	GreySource
15	The Grey Literature Report
16	Proquest Dissertations

531

532 Table 2. Data extraction table

Categories	Extraction Items
General	Author(s); title; funding source(s)
Method	Design: objectives of the study; target behavior(s); duration of the study; study location; recruitment setting, date of study
	Participants: population characteristics, inclusion and exclusion criteria; number of participants; age, gender, weight status, socio-demographic information
Intervention	Frequency and length of sessions; intervention duration; intervention setting; intervention provider; access of the application; behavioral change techniques; mode of delivery, components of the intervention; theoretical framework, the use of prompts/reminders, co-interventions
Outcomes	Measurement unit; Measurement type; measurement tool; follow-up duration and frequency; mean and standard deviation at baseline, post-intervention, and follow up; effect size; attrition rate/diagram; participants' perception of interventions, engagement and usage rates of the app

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Dear Editors and Reviewers,

We are grateful to the reviewers for your positive comments to our revised version.

Abstract
I am still not convinced as to the wording 'critical phase to adopt a lifestyle', please revise - this could be stated perhaps as a transitional life stage instead. Same applies to my later comment relating to the introduction.

Thank you for this suggestion. We agree that the wording “transitional life stage” will be more appropriate than “critical phase” to represent “university stage”. However, we intended to emphasize that this transitional stage is an important stage for adopting lifestyle. Thus, we revised “critical phase” into “transitional stage”, but we kept adding a statement highlighting that this stage is important for adopting a particular lifestyle (line 7-9, line 47-49).

Methods
Participants
I am still unclear as to why you are excluding sports students - and the underlying assumptions here - *please justify* - probably worth a sentence to clarify in the manuscript, or at least include the reference cited in the response?

We are grateful for this suggestion. Previously, we had made a decision based on other authors' assumptions regarding the different motivations for sports participation among sport students than students in other faculties (Kondric et al., 2013). Thus, we amended our plan. We will not exclude sports students (line 93-95), but we will conduct a sensitivity analysis to test whether excluding studies specifically designed for sports students will influence the effectiveness of the intervention (line 251-253).

Discussion
Good to read the re-statement of the aim - suggest re-wording to aid readability - something like:
University students represent an important population group to target for PA intervention, because this age group typically do not meet physical activity guidelines (reference needed). Furthermore, the transition to university represents a critical period for adopting a particular lifestyle (reference).

We thank the reviewers for this suggestion. We are happy to revise our discussion opening. We think that your suggestions will improve the readability of our discussion section. Thus, we reword our sentences as suggested (line 261-264).

Those are our responses to your feedback and comments. We appreciate any feedback you have given us on our manuscript.

Sincerely,

Authors